White River Algae
Report on 2016 Data

Prepared by Colorado Parks and Wildlife: October 18, 2017

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Algae bloom in the White River at Wakara, July 2016.

I. Executive Summary

In 2016, Colorado Parks and Wildlife (CPW) continued investigation of a filamentous algae bloom in the White River that impacts angling. The visible filamentous alga was identified as *Cladophora glomerata*. A nutrient addition experiment identified nitrogen as the nutrient limiting algal growth, indicating that further addition of nitrogen will stimulate additional algal growth. Coal Creek is a major source of nutrients (both nitrogen and phosphorus) to the lower portion of the mainstem White River, but nutrient availability is sufficient to support nuisance blooms at least 24 river-miles upstream of Coal Creek. Human sources of nutrients include septic systems, fish food, sediment, animal waste, and fertilizers. Reduction of both nitrogen and phosphorus is recommended to reduce nuisance algal growth in the White River, with particular emphasis on nitrogen reductions (Dodds & Smith 2016).

II. Data Collection

In 2016, CPW collected data from 16 sites in the White River and Coal Creek watersheds (Figure 1 and Table 1). Field measurements and water-quality samples were collected monthly from March through October at 15 of those sites (Table 2). Macroinvertebrates samples were collected from 9 sites in September, and a nutrient addition experiment and periphyton were collected at 5 sites in July (periphyton ID and count at one site).

Table 1. Site List and Samples Collected.

Site ID	Site Description	Lat	Long	Water Quality	Macro-inverts	Nutrient Addition Experiment	Chl a	Algae ID
6111	N. Fk. White R. blw. Lost C.	40.048284	-107.46994	X	X	X	X	
6110	N. Fk. White R. @ CR 14	40.01147	-107.55807	X	X			
6109	N. Fk. White R. Abv. Westlands	39.999358	-107.58608	X				
6108	N. Fk. White R. @ Westlands	39.997722	-107.59053	X	X	X	X	
6107	N. Fk. White R. @ Bel Aire	39.979058	-107.63047	X	X			
6106	S. Fk. White R. @ Bel Aire	39.97484	-107.62739	X	X	X	X	
6105	White R. @ Sleepy Cat	39.950112	-107.69475	X	X			
6104	White R. @ Wakara	40.006063	-107.82519	X	X	X	X	X
6103	White R. @ Meeker Pasture	40.033632	-107.84710	X	X		X	
6102	White R. @ Bailey's Bridge	40.036522	-107.8832			X		
531	White R. 5th St. Bridge	40.034631	-107.91162	X	X			
6112	Coal Cr. @ CR 8	40.033656	-107.83288	X				
6113	Coal Cr. @ CR 6	40.030919	-107.82209	X				
6114	Coal Cr. @ Lunney Ranch	40.085553	-107.7728	X				
6115	Little Beaver Cr. @ CR 6	40.030933	-107.7996	X				
6116	Little Beaver Cr. @ CR 40	40.03315	-107.71635	X				

Table 2. Sample dates and activities.

Date	Activities
August 31, 2015	• water quality (results not reported here, see previous report) • macroinvertebrates
March 17, 2016	• field parameters • water quality
April 29, 2016	• field parameters • water quality
May 26, 2016	• field parameters • water quality
June 21, 2016	• field parameters • water quality
July 19, 2016	• algae biomass • algae ID • deployed nutrient addition trays
July 20, 2016	• field parameters • water quality
August 17, 2016	• retrieve nutrient addition trays
August 18, 2016	• field parameters • water quality
September 22, 2016	• field parameters • water quality • macroinvertebrates
October 20, 2016	• field parameters • water quality

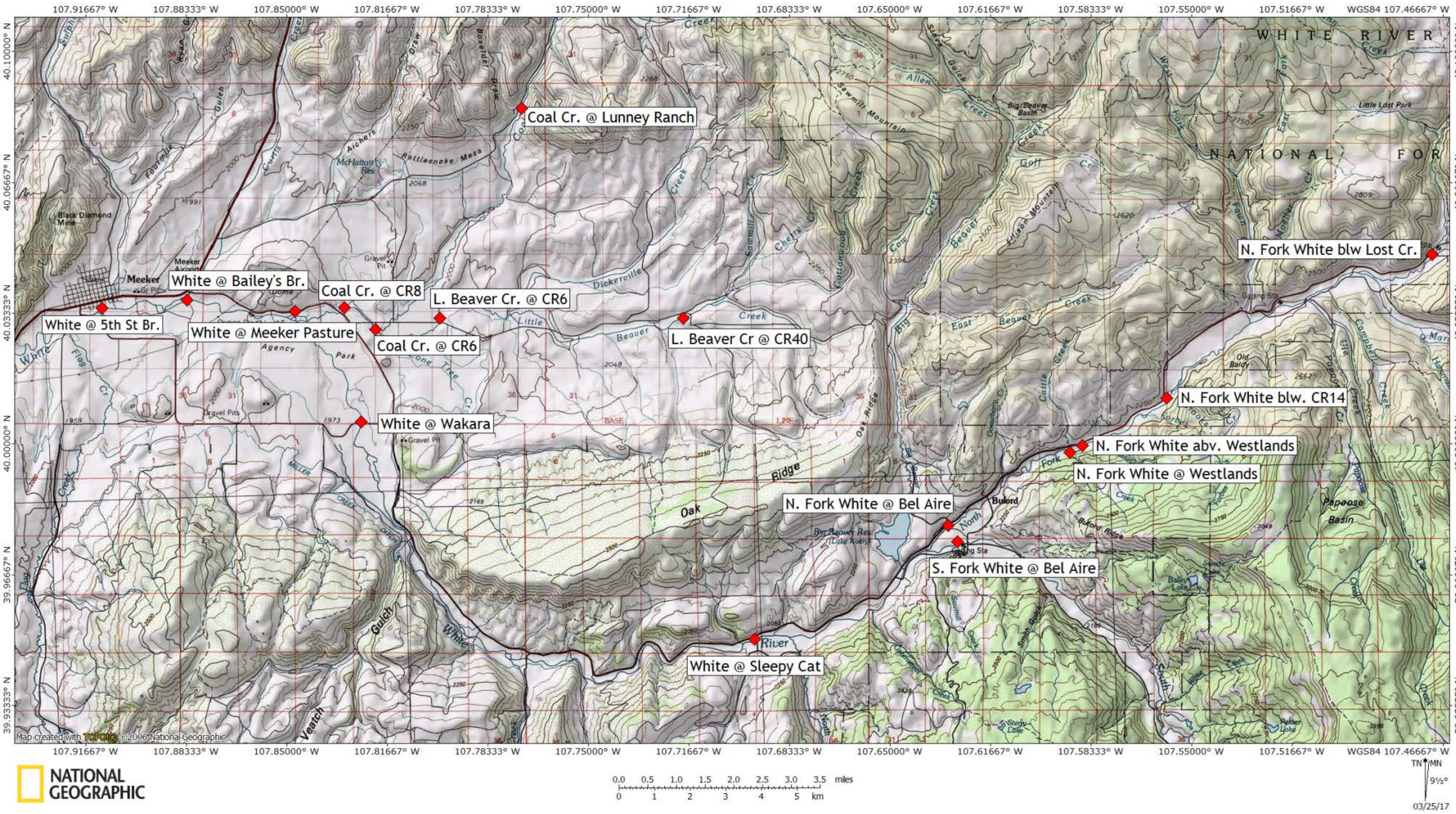


Figure 1. Map of 2016 sampling sites.

Field measurements included temperature, specific conductivity, dissolved oxygen, pH and turbidity.[1]

Water samples were not filtered, and were kept on ice or refrigerated until they were received by the lab. Nutrient samples were preserved by immediately acidifying them with sulfuric acid. Water samples were analyzed by River Watch (RW) and Metro Wastewater Reclamation District (Metro) (Table 3).

Benthic algae were collected following the Colorado Water Quality Control Division's (WQCD) periphyton procedures (WQCD 2015). Chlorophyll a analysis, species identification and cell counts were completed by the Center for Limnology at University of Colorado, Boulder (Table 3).

Macroinvertebrate samples were collected and scored following Water Quality Control Commission Policy 10-1 (WQCC 2017). Species were identified and counted by Timberline Aquatics (Table 3).

Table 3. Laboratory analyte list and method information.

Lab	Analyte	Method	Reporting Limit
River Watch	Chloride	EPA 325.1	1.0 mg/L
	Sulfate	EPA 375.4	0.5 mg/L
	TSS	EPA 160.2	4.0 mg/L
	Nitrate + Nitrite	EPA 353.2	0.02 mg/L
	Total Phosphorus	EPA 365.1	0.005 mg/L
Metro	Nitrate + Nitrite	EPA 353.2 rev2	0.02 mg/L
	Total Kjeldahl nitrogen	ASTM D3590-02B06	0.2 mg/L
	Total Nitrogen	calculated	0.3 mg/L
	Total Phosphorous	4500-P-H 99,21st	0.01 mg/L
CU Center for Limnology	Chlorophyll a	Marker et al. 1980; Nusch 1980	0.06 ug
	Periphyton ID and cell count	NA	NA
Timberline Aquatics	Macroinvertebrate ID and count	WQCC 2017	NA

A nutrient enrichment study was conducted for 4-weeks in July and August to determine whether nitrogen and/or phosphorus would stimulate algal growth. Tubes containing various combinations of agar, nitrogen and phosphorus were anchored to the stream bottom and colonized by algae for four weeks (Table 4). Algal growth on the tubes was measured at the end of the study to determine which nutrient, or nutrient combination, stimulated growth.

Table 4. Nutrient addition experimental groups (prepared following WQCD methods).

Group	% Agar	Nutrient Supplement	Nutrient Concentration
Control (C)	2.0	None	none
Nitrogen Addition (N)	2.0	NH_4NO_3	0.5 moles N/L agar
Phosphorous Addition (P)	2.0	K_2HPO_4	0.2 moles P/L agar
Nitrogen and Phosphorus Addition (N+P)	3.0	NH_4NO_3 + K_2HPO_4	0.5 moles N + 0.2 moles P/L agar

Agar and nutrients were added to distilled de-ionized water and heated. Pre-labeled polystyrene tubes (48 mL) were filled with one of the four solutions (control, N, P and N+P), allowed to cool and solidify, and then capped. Caps consisted of a 2.7 cm fritted glass-disc crucible cover (Leco Corporation, St.

[1] A YSI Pro-DSS was used to measure field parameters from May through October. In March and April, a YSI 85 was used to measure temperature, dissolved oxygen and specific conductivity, and a Hach kit was used to measure pH. No turbidity measurements were collected in March or April.

Joseph, MI, USA) that allowed nutrients to slowly diffuse out of the tube, and a snap cap with a 0.75 in. diameter hole that standardized the area that could be colonized by algae (Figure 2).

In July, trays containing 20 vials (5 replicates of each treatment group) were anchored to the stream bottom at five sites (Table 1). The trays were retrieved on August 17, after 29 days in-stream. At the time of retrieval, algal biomass was measured with a Benthotorch (bbe Moldanke, Schwentinental, Germany) on the surface of the glass lids, which was accessible to macroinvertebrate grazers, and on the agar underneath the lid, which was not accessible to grazers. The discs were also sent to the Center for Limnology for chlorophyll a analysis by ethanol extraction.

Figure 2. The left panel shows the tubes filled with agar. The left tube is unassembled showing the tube filled with agar, porous glass disk, and cap. The right tube is fully assembled. The right panel shows the tubes being tied into the tray.

Flows were near historic averages during most sampling activities, with the exception of late August and early September when flows were lower than normal (Table 2, Figure 3).

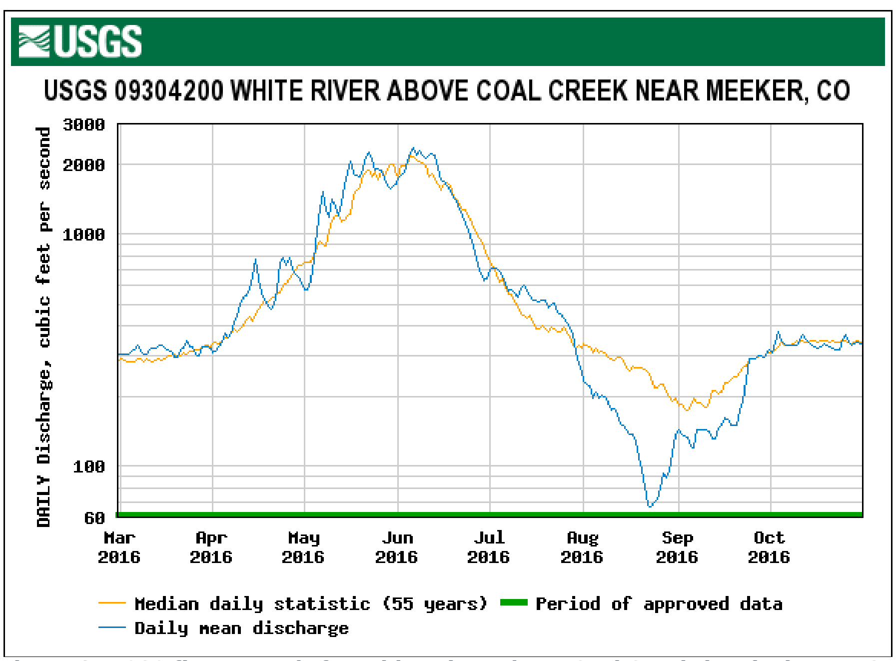


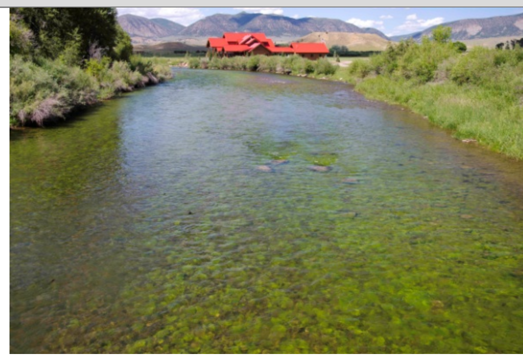
Figure 3. USGS flow records for White River above Coal Creek (equivalent to CPW sampling site 6104 at Wakara). Flows in 2016 were close to historic averages during most of CPW's sampling in 2016. Flows were lower than normal in late August and early September.

III. Algae Results and Discussion

Periphyton is the community of bacteria, protozoa, fungi and algae attached to cobbles and other submerged surfaces in aquatic environments. There are multiple ways to measure the biomass of periphyton and its various components. Since the nuisance growth impacting angling is algal, CPW selected chlorophyll a, which measures the pigment in living photosynthetic organisms (Steinman and Lamberti 1996). Measuring chlorophyll a is advantageous because it excludes biomass from the non-photosynthetic component of periphyton including fungi, dead algae, non-photosynthetic protozoans and bacteria. One drawback of using chlorophyll a to measure biomass is that cells of equivalent biomass can have varying amounts of chlorophyll.

CPW sampled periphyton at five sites in 2016: North Fork White River below Lost Creek, North Fork White River @ Westlands, South Fork White River at Bel Aire, White River at Wakara, and White River at Meeker Pasture (Table 5).

Table 5. Photographs of sites sampled for periphyton July 19 and 20, 2016.

North Fork White below Lost Creek	North Fork White at Westlands
	
South Fork White at Bel Aire	White at Wakara
	
White at Meeker Pasture	
	

The North Fork of the White below Lost Creek had less algal biomass compared to the other sites sampled (Table 5, Figure 4).

With the exception of the North Fork below Lost Creek, all of the sites sampled for periphyton exceeded Colorado's standard of 150 mg/m^2 chlorophyll a (WQCC 2016; Figure 4). Three of these sites, (Westlands, Wakara, and Meeker Pasture), were affected by heavy growths of filamentous algae at the time they were sampled (Table 5).

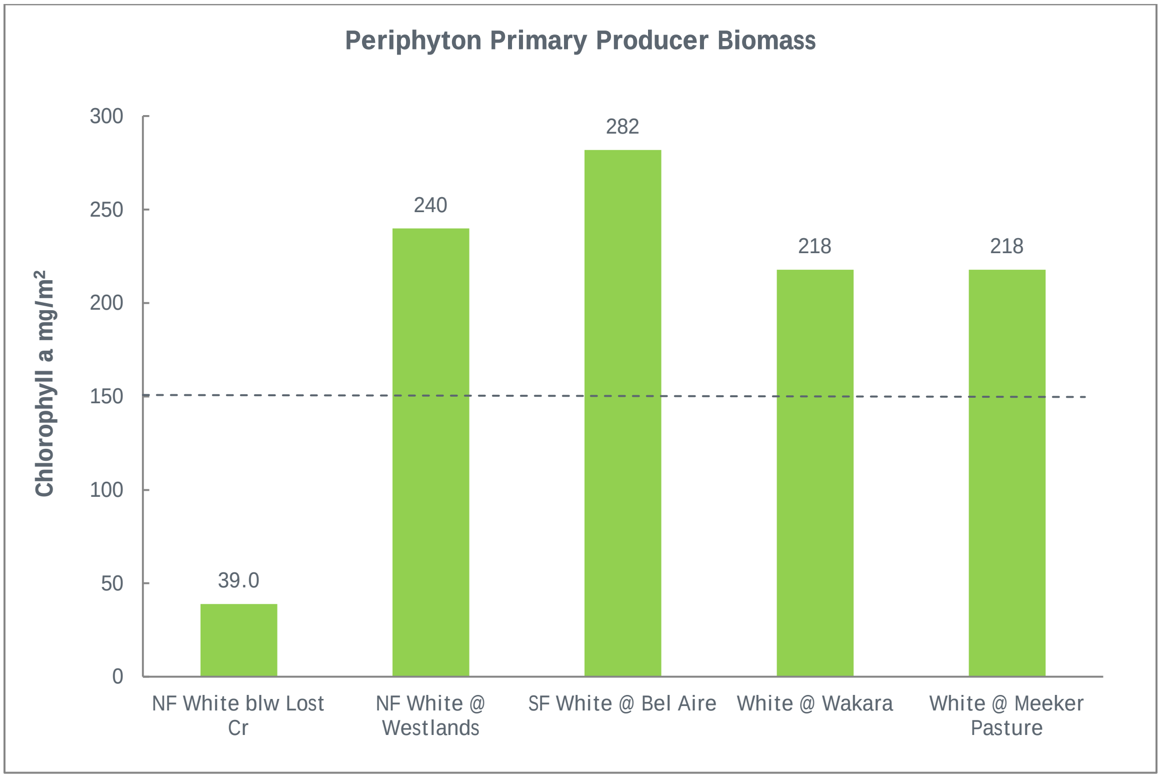


Figure 4. Comparison of periphyton biomass measured July 19, 2016. The dashed line is Colorado's chlorophyll a standard of 150 mg/m^2.

Surprisingly, the site with the highest chlorophyll a was the South Fork at Bel Aire, which was not affected by *Cladophora glomerata*. Although the South Fork does not have the filamentous growths of algae, there is a thick crust of less-noticeable algae growing on the rocks.

The White River at Wakara had abundant periphyton, including heavy growths of long filamentous algae. Blue-green algae, diatoms, and green algae were identified at Wakara (Table 6, see Appendix C for full results).

Table 6. Overview of taxonomic groups of algae and cyanobacteria identified at Wakara July 19, 2016,		
Common Name	Scientific Name	Number of species identified
Blue-Green Algae	Cyanobacteria	5
Diatoms	Bacillariophyta	42
Green Algae	Chlorophyta	2

The visible filamentous alga present at Wakara was identified as *Cladophora glomerata*, a type of green algae (Chlorophyta) (Figure 5 & Figure 6). Another filamentous green algae *Ulothrix zonata* was also present, but less abundant than *Cladophora*.

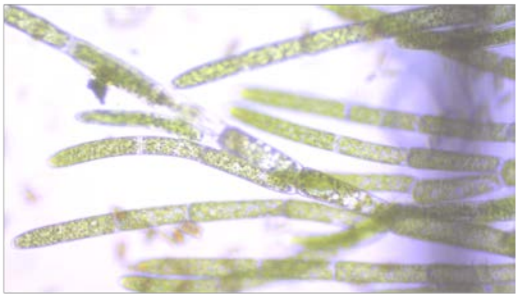


Figure 5. Microscopic photo of *Cladophora glomerata* collected in the White River in 2016, magnification 100x.

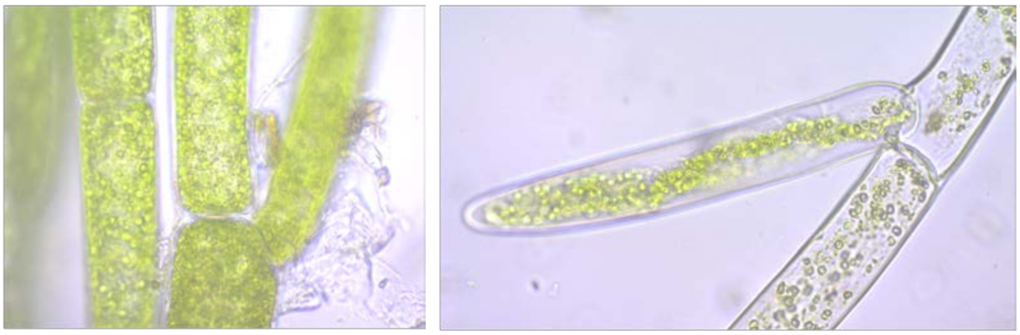


Figure 6. Microscopic photos of *Cladophora glomerata* collected in the White River, magnification 400x.

Cladophora glomerata is a filamentous green alga with varied degrees of branching. Nuisance levels of *C. glomerata* have previously been reported in other Western rivers, including the Clark Fork River in Montana (Lohman & Priscu 1992). *C. glomerata* growth rate increases in response to increased nutrients, warm temperatures (about 70^{o}F, but variable temperature preferences have been reported), high light availability, alkaline waters (pH between 7.3 and 9.0), and hard water (Dodds & Gudder 1992; Whitton 1970). Some authors have observed that *C. glomerata* prefers areas of higher flows, but not so high as to the break the filaments (Whitton 1970). This is consistent with our observations in the White River, where lighter growths occurred in slow-moving water along banks, and heavier growths occurred in fast-flowing riffles and deeper portions of the channel. Whiton (1970) theorized this gives the alga greatest access to nutrients, which are replenished more rapidly in higher velocity water.

High flows/current can temporarily control *C. glomerata* biomass by scouring the alga from rock surfaces, but re-growth will occur as long as nutrient availability is sufficient and other growth requirements are still met. Investigations for controlling nuisance levels of benthic algae have generally focused on reducing nutrient levels (Dodds and Welch 2000; Dodds et al. 1997). Some authors have recommended planting shade trees in riparian areas to reduce light availability for *C. glomerata* (Whitton 1970). *Cladophora* is not a preferred food source for freshwater macroinvertebrate grazers (Dodds 1991; Dodds & Gudder 1992).

IV. Algal Response to Nutrient Additions

Algae and cyanobacteria response to experimental nutrient additions were measured at five locations: North Fork below Lost Creek, North Fork at Westlands, South Fork at Bel Aire, White at Wakara, and White at Bailey's Bridge.

Macroinvertebrate grazers prefer the enriched algae growing on top of the disks, and the grazing rate on those disks is not representative of instream grazing rates. This report focuses on algal growth measured with the Benthotorch on the agar under the disks, which is not subject to grazing by macroinvertebrates. The results reported here represent relative algal growth response to the addition of nutrients.

No data on nutrient additions are reported for the White at Wakara, because the trays dried-out after water levels at that site dropped significantly about three-weeks after the start of the experiment. Measurements from the remaining sites were statistically analyzed with a Kruskall-Wallis test in Minitab 17.3.1 (α=0.050). At all sites, nitrogen produced significantly more algal growth than phosphorus (Figure 7). Similar to the White River, *Cladophora* blooms in the Clark Fork and Madison Rivers also showed nitrogen limitation (Dodds 1991; Dodds et al. 1997). Nitrogen limitation in freshwaters was once thought to be rare, but recent analysis has shown nitrogen limitation is equally as common as phosphorus limitation (Francoeur et al. 1999; Dodds & Welch 2000). Adding both nutrients produced greater algal growth than adding nitrogen alone.

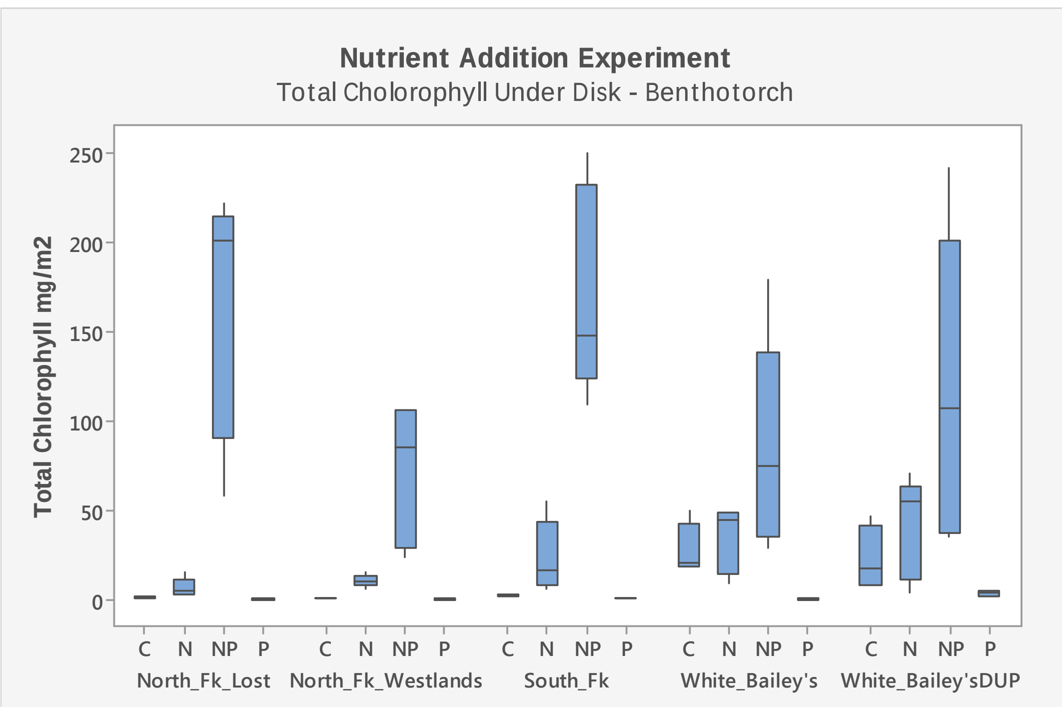


Figure 7[2]. Comparison of total periphyton (cyanobacteria+green+diatom) growth on agar in response to nutrient additions.

[2] All box-and-whisker plots in the report display the inner quartile as a blue-box. The top of the blue box is the 75th percentile of data, but bottom of the blue box is the 25th percentile, and median (50th percentile) is a line in the middle of the box. The upper whisker extends to the maximum data point within 1.5 box heights from the top of the box, and the lower whisker is the minimum data point within 1.5 box heights from the bottom of the box. Asterisks mark data points higher or lower than the whiskers.

V. Macroinvertebrate Scores

Macroinvertebrate samples were collected on September 22, 2016. These samples and samples collected August 31, 2015 were scored using the WQCD's multi-metric index (MMI). MMI scores range from zero to 100, with higher scores generally indicating a healthier macroinvertebrate community. Sites with scores greater than 64 are considered "high scoring". Sites with scores less than 42 are considered impaired.

MMI scores for both years generally decreased from upstream to downstream, and the sites most impacted by filamentous algae had the lowest scores (Figure 8). Only the two most upstream sites on the North Fork (Lost Creek and CR14) were "high scoring" sites. Three sites on the mainstem had scores below the impairment threshold: Wakara, Meeker Pasture, and Bailey's Bridge.

Sites sampled in both 2015 and 2016 generally had similar scores. The largest decrease in MMI scores from 2015 to 2016 occurred at Westlands and Wakara, which both had decreases of 6-points.

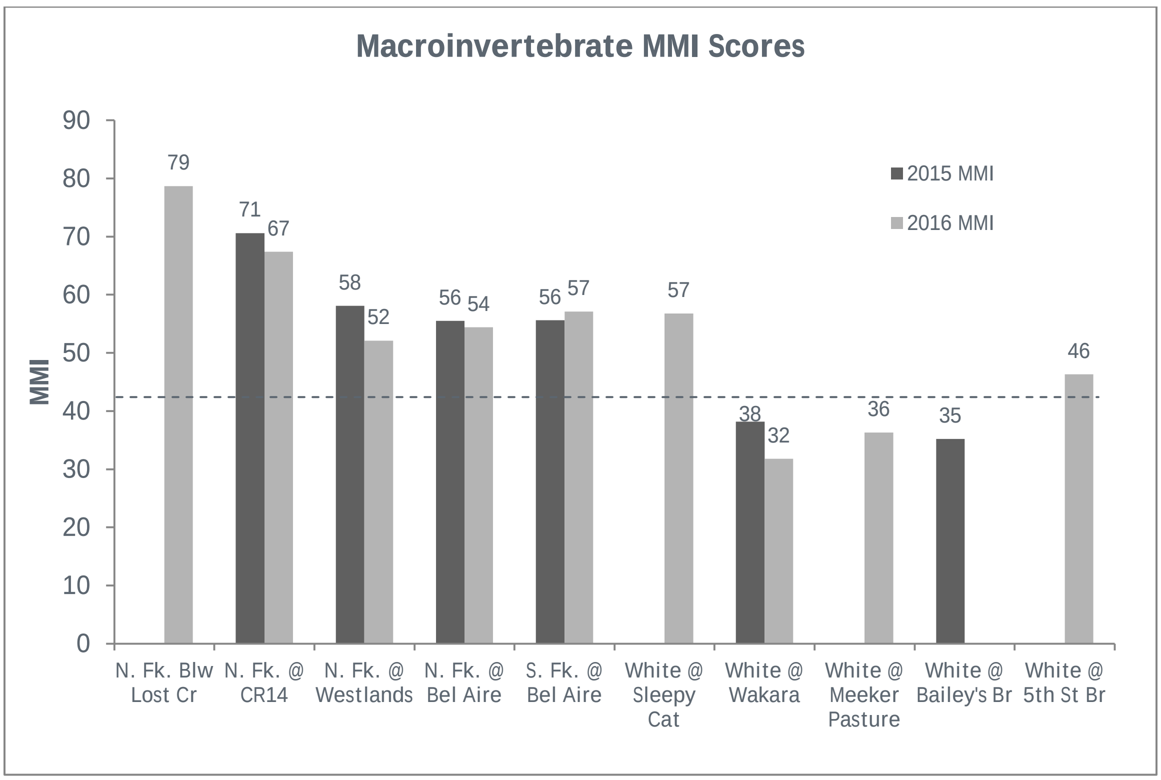


Figure 8. Macroinvertebrate MMI scores. The dashed line is Colorado's impairment threshold of 42.

VI. Nutrient Data

Nitrogen and phosphorus come in a variety of chemical forms, some of which are more bio-available than others (Table 7).

Table 7. Nutrient availability.			
Parameter	Most bioavailable	Moderately bioavailable	Less bioavailable
Nitrogen	Ammonia (NH_3)	Nitrate (NO_3) Nitrite (NO_2)	Organic Nitrogen
Phosphorus	Phosphate (PO_4)		Organic Phosphorous

Total nitrogen and total phosphorus are the focus of this analysis, rather than the more bioavailable forms only, for several reasons:

1. The microbial community converts less bio-available forms into more bio-available forms, particularly when nutrients are in short supply (Dodds 1993).
2. Total nitrogen and total phosphorus are better predictors of benthic algae than analysis of the more bioavailable forms (ex. soluble reactive phosphorus (SRP), or dissolved inorganic nitrogen (DIN) (Dodds et al. 2003).
3. Modern nutrient thresholds for rivers and streams apply to total nitrogen and total phosphorus (Chambers et al. 2012;Dodds et al.. 1997; Dodds & Welch 2000;Dodds 2003;WQCC 2016) (Table 7).

   Colorado has interim thresholds for nitrogen and phosphorus for cold water streams (Table 8). For comparison, the total nitrogen and total phosphorus concentrations associated with significant increases in average benthic algae identified by Dodds et al. (2002) are also included.

Table 8. Nutrient thresholds.		
Parameter	Colorado's thresholds for coldwater streams	Dodds et al. 2002
Total Nitrogen	1.250 mg/L	0.040 mg/L
Total Phosphorus	0.110 mg/L	0.030 mg/L

The nutrient results reported below are from Metro only, since RW did not have the capability to analyze total nitrogen when these samples were collected.

A. Nitrogen

Spatial variation

Total nitrogen concentrations were lowest in the South Fork of the White River and highest at Meeker Pasture, which is just downstream of Coal Creek (Figure 9). Coal Creek is a major source of nutrients to the White River, and concentrations of total nitrogen were high throughout the Coal Creek watershed (Figure 10). The median total nitrogen concentrations at all sampling sites were below Colorado's total nitrogen threshold of 1.250 mg/L, but exceeded Dodd et al.'s threshold of 0.040 mg/L.

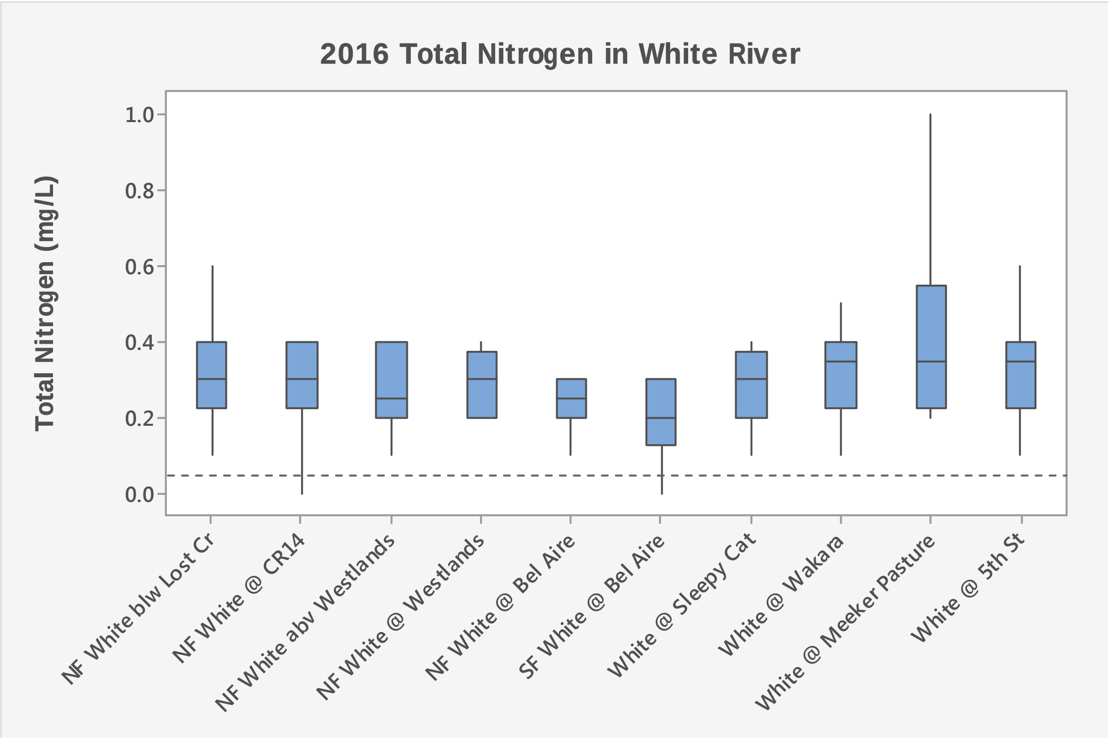


Figure 9. Comparison of total nitrogen across all sample sites on the White River. Dashed line at 0.040 mg/L TN is the threshold above which mean chlorophyll values substantially increase (Dodds et al. 2002). Colorado's TN threshold of 1.250 mg/L is not shown.

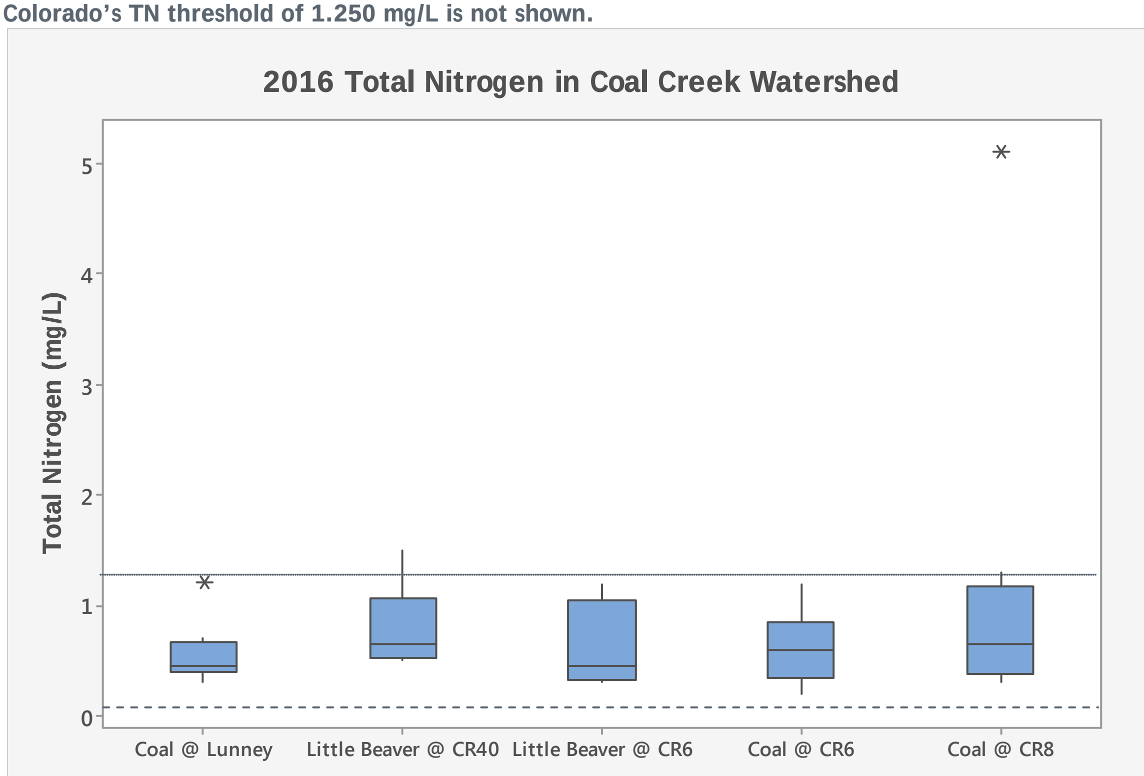


Figure 10. Comparison of total nitrogen across all sample sites in the Coal Creek watershed. Dashed line at 0.040 mg/L TN is threshold above which mean chlorophyll values substantially increase (Dodds et al. 2002). The dotted line at 1.250 mg/L TN is Colorado's threshold.

Seasonal Variation

At most sites on the White River, the highest total nitrogen concentrations occurred during spring runoff, and the lowest concentrations occurred in March before spring runoff and mid-summer when algal growths were peaking (Figure 11). In Coal Creek, the seasonal pattern was similar to the White with the exception of a large spike in total nitrogen in September near the mouth of Coal Creek (Coal Creek @ CR8) (Figure 12). The low concentrations in mid-summer may be due to high nutrient demand by rapidly growing algae. When algae are growing rapidly, they quickly remove available nutrients from the water column.

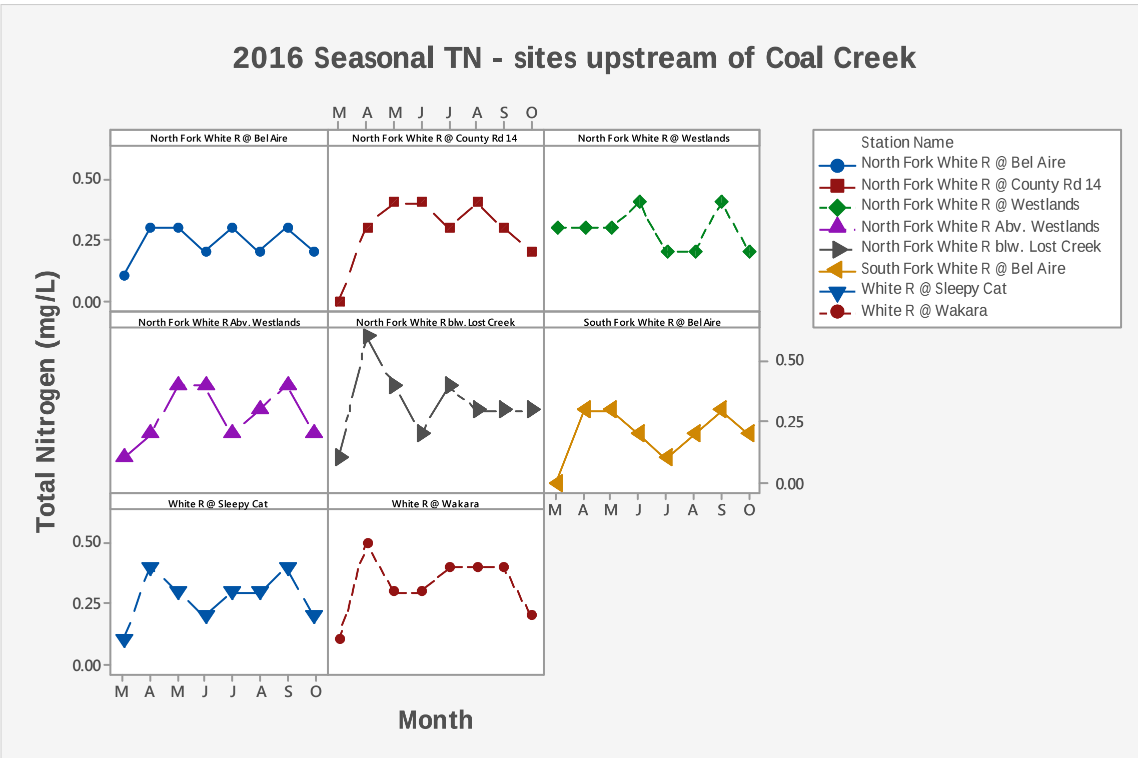


Figure 11. Seasonal comparison of total nitrogen for sites upstream of Coal Creek.

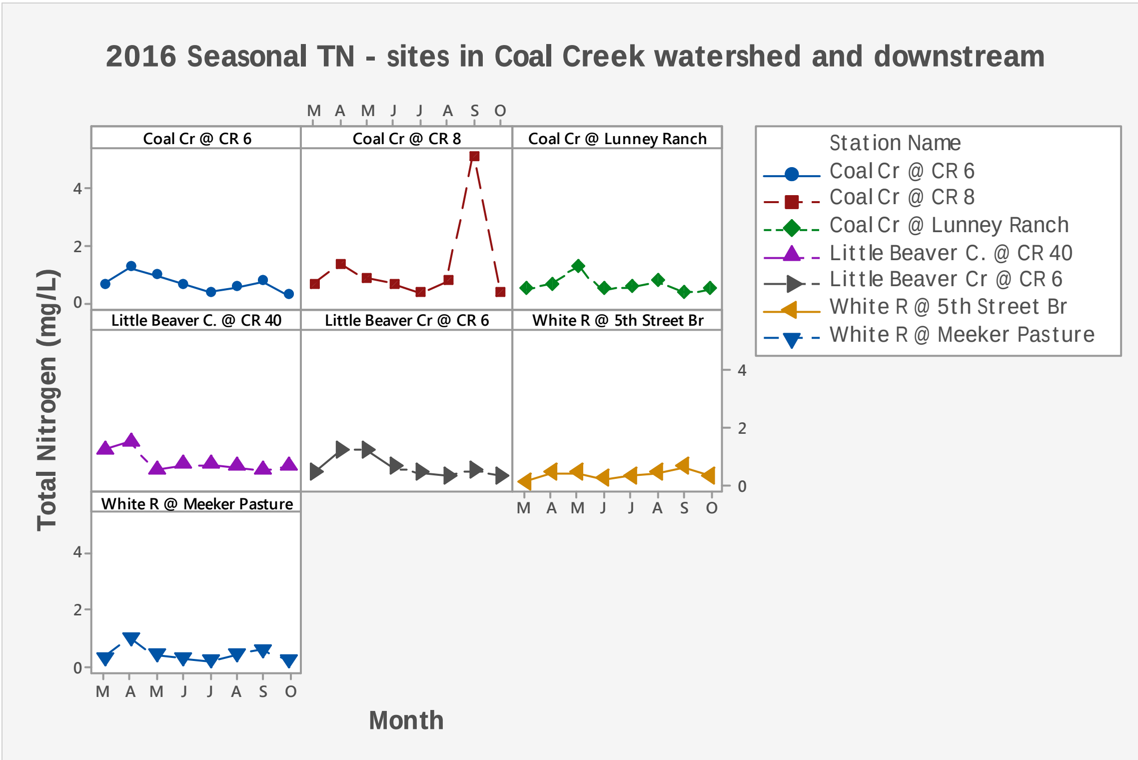


Figure 12. Seasonal comparison of total nitrogen across all sample sites in the Coal Creek watershed.

B. Phosphorus

Spatial variation

Total phosphorous concentrations were lowest in the White River watershed upstream of Coal Creek and highest at Meeker Pasture, which is just downstream of Coal Creek (Figure 13). Coal Creek is a major source of nutrients to the White River, and concentrations of total phosphorus were high in the lower sites in the Coal Creek watershed (Figure 14).

The median total phosphorus concentrations at all sites were below Colorado's total phosphorus threshold of 0.110 mg/L. Five sites exceeded Dodd et al.'s threshold of 0.030 mg/L: Little Beaver @ CR6, Coal Creek @ CR6, Coal Creek @ CR8, White River @ Meeker Pasture, and White River @ 5th Street Bridge.

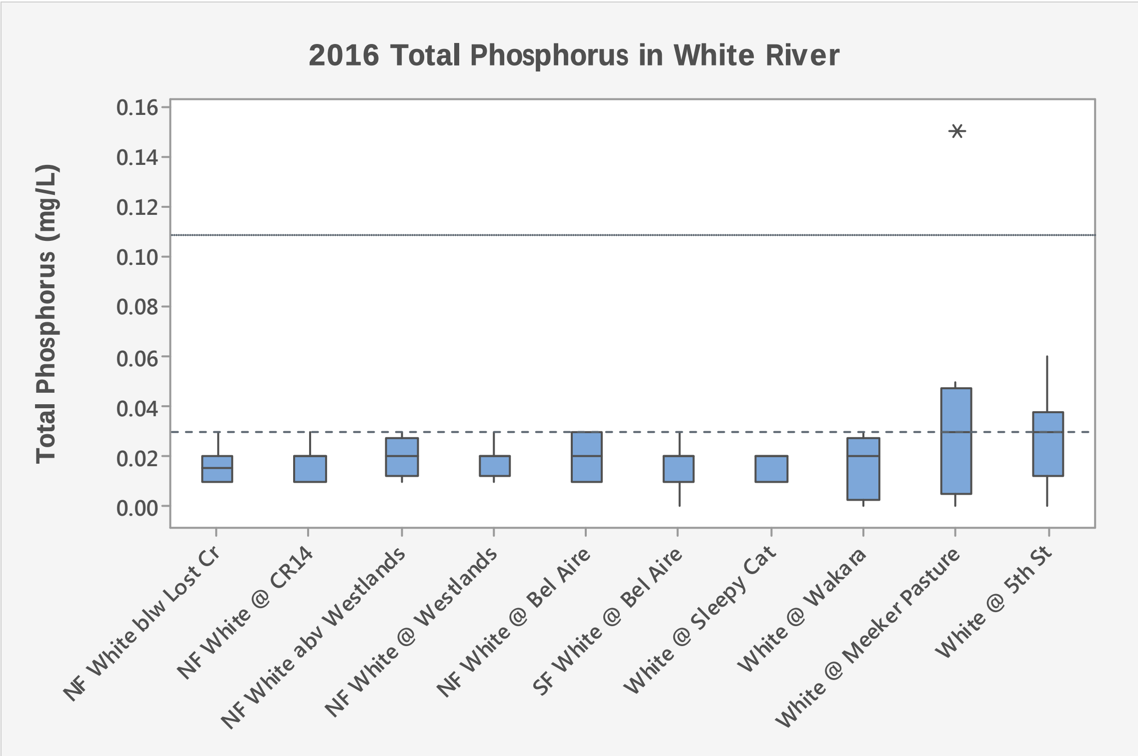


Figure 13. Comparison of total phosphorus across all sample sites on the White River. The dashed line at 0.030 mg/L TP is the threshold above which mean chlorophyll values substantially increase (Dodds et al. 2002). The dotted line at 0.110 mg/L TP is Colorado's threshold.

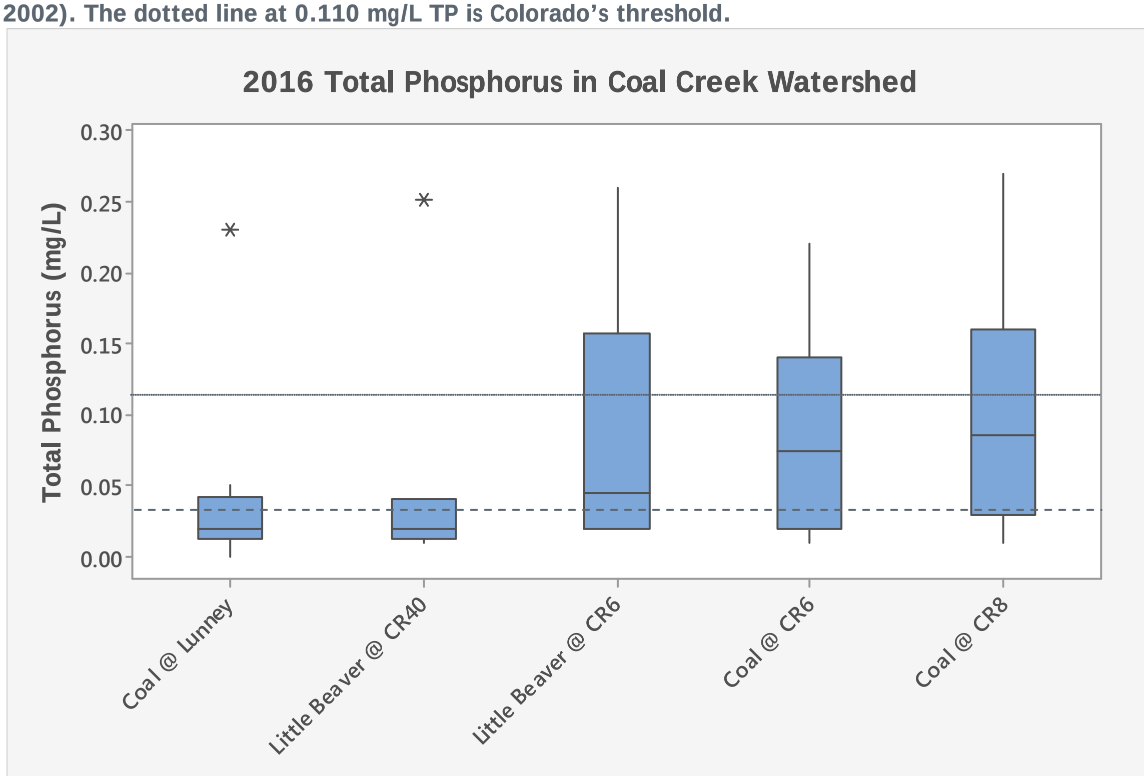


Figure 14. Comparison of total phosphorus across all sample sites in the Coal Creek watershed. The dashed line at 0.030 mg/L TP is threshold above which mean chlorophyll values substantially increase (Dodds et al. 2002).

Seasonal Variation

At most sites on the White River, the highest total phosphorus concentrations occurred during spring runoff, and the lowest concentrations occurred in March before spring runoff and mid-summer when algal growths were peaking (Figure 15). In Coal Creek, the seasonal pattern was similar to the White with the exception of a spike in total phosphorus in August and September at the two most downstream sites in the Coal Creek watershed (Coal Creek at CR6 and Coal Creek @ CR8) (Figure 16). The low concentrations in mid-summer may be due to high nutrient demand by rapidly growing algae. When algae are quickly growing, they remove nutrients from the water column and incorporate them into their biomass.

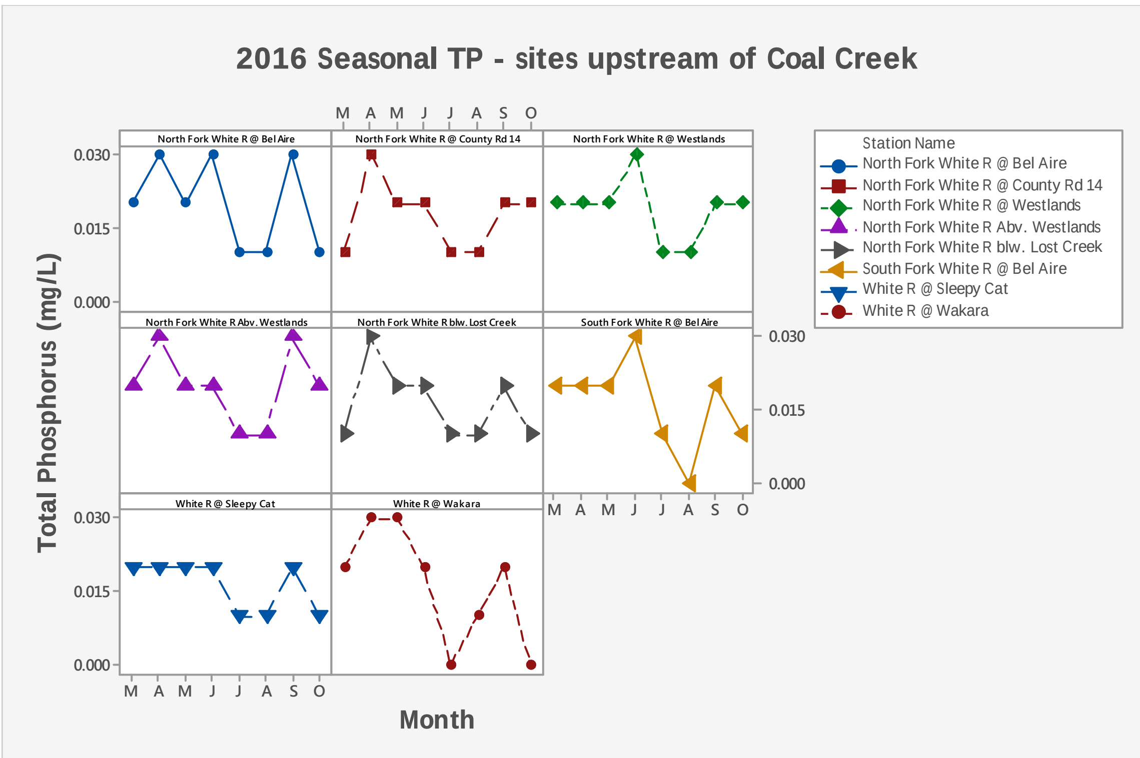


Figure 15. Seasonal comparison of total phosphorus across all sample sites upstream of Coal Creek.

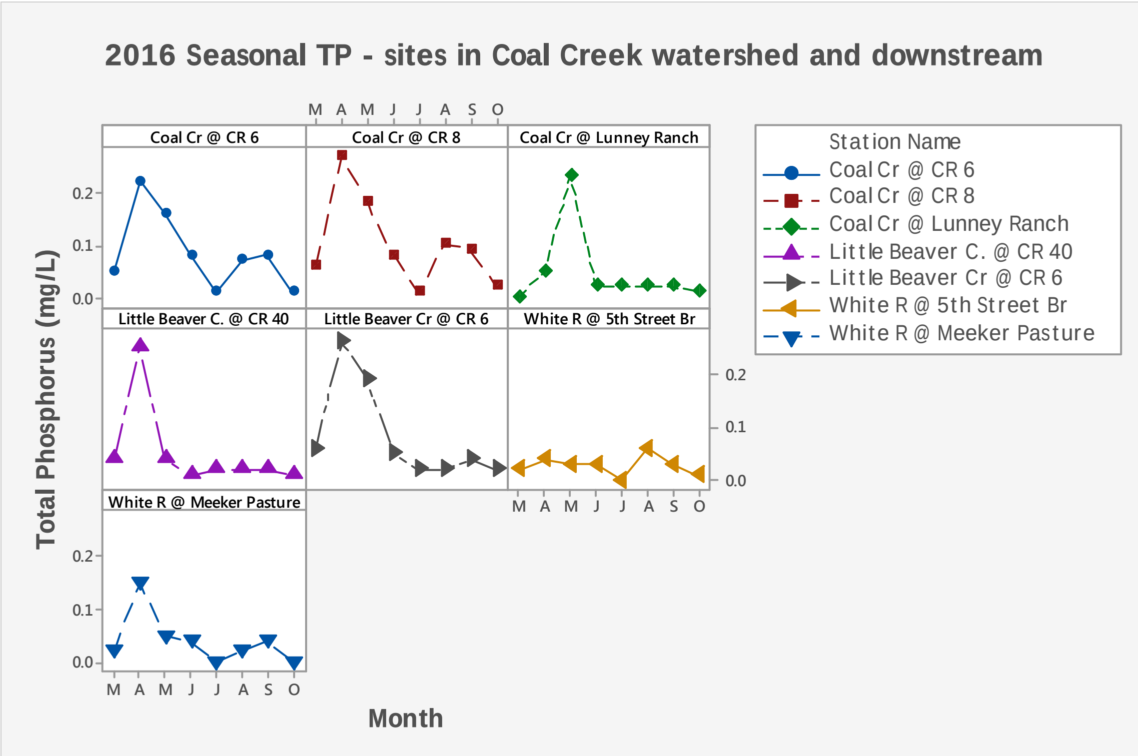


Figure 16. Seasonal comparison of total phosphorus across all sample sites in the Coal Creek watershed and in the White River downstream of Coal Creek.

Cladophora does not require a continual source of phosphorus for growth. When phosphorus availability exceeds growth requirements, *Cladophora* is capable of storing the excess phosphorus for use when the nutrient is less available (Lohman and Priscu 1992, Dodds and Welch 2000). This ability to store phosphorus may explain why *Cladophora* is often limited by nitrogen rather than phosphorus.

C. Field Parameters

Field parameters influenced by algal growth are summarized here.

pH

All sites and measurements were alkaline (above pH 7). No site exceeded Colorado's upper pH standard of 9.0 or the lower pH standard of 6.5 (Figure 17 & Figure 18). In the White River, pH generally increased from upstream-to-downstream, which may be an artifact of the order the sites were sampled and related to time of pH measurement.

Algae absorb carbonic acid (dissolved carbon dioxide) during photosynthesis. This removal of carbonic acid increases the pH of the surrounding water. At night, algae release carbon dioxide as a byproduct of respiration, which forms carbonic acid in water, and lowers the pH. When algae are abundant, large diel changes in pH occur as photosynthesis increases pH during the day, and respiration reduces pH at night. pH below 6.5 or above 9.0 is stressful to fish and other aquatic organisms.

CPW worked upstream-to-downstream while collecting samples. Therefore, upstream sites are expected to have lower pH since they were collected in the morning. Water-quality sondes that can be deployed at a site and periodically measure pH would be better for tracking diel pH changes caused by excessive growths of algae that may be stressful for fish. CPW does not own this type of logging equipment.

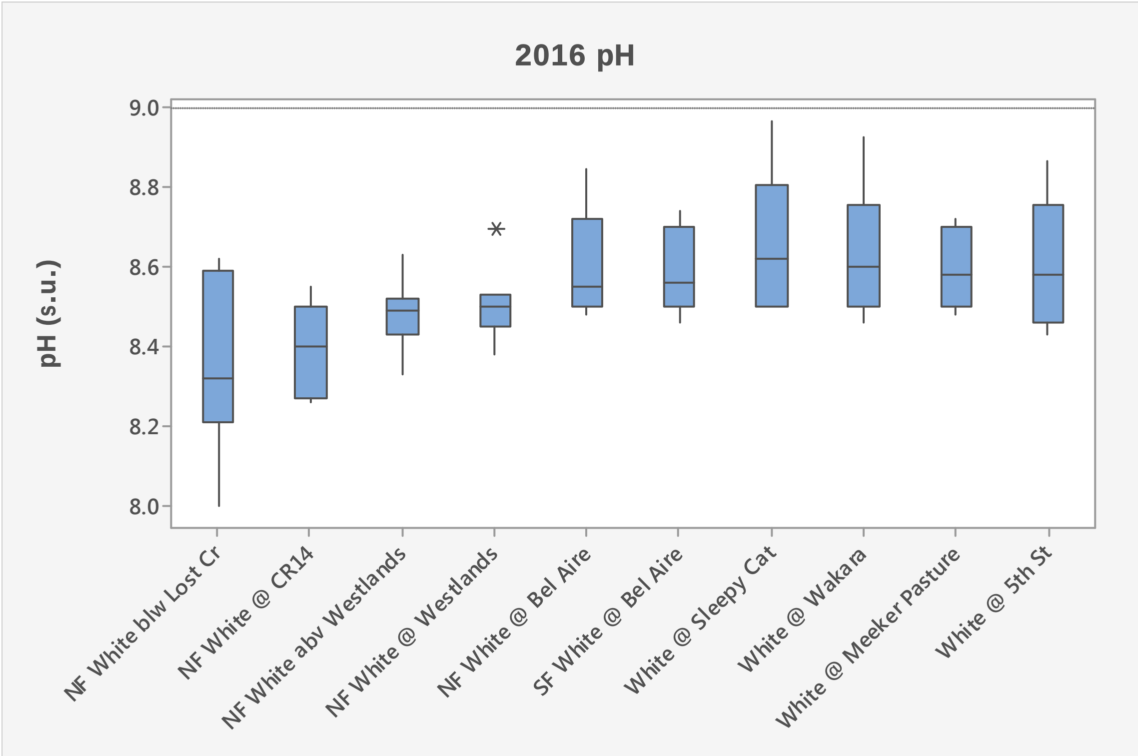


Figure 17. Comparison of pH across all sample sites on the White River. The dotted line at 9.0 is Colorado's upper pH standard.

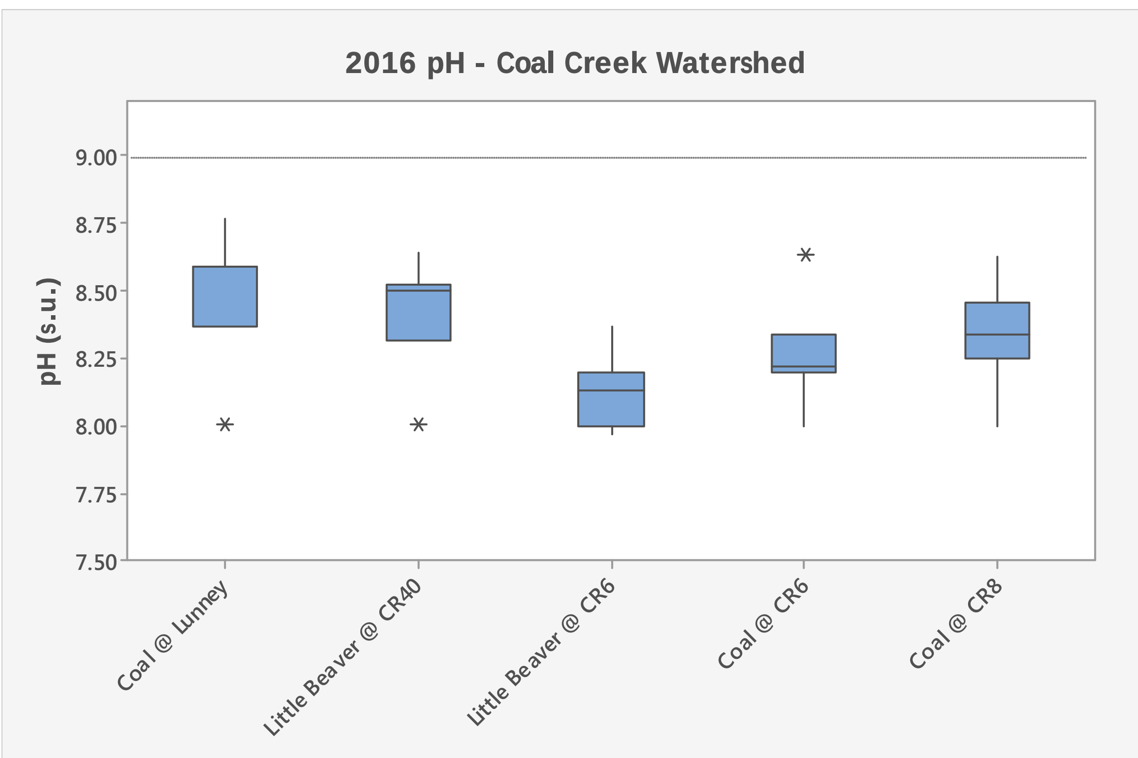


Figure 18. Comparison of pH across all sample sites in the Coal Creek watershed. The dotted line at 9.0 is Colorado's upper pH standard.

Dissolved Oxygen

All samples and measurements were above Colorado's minimum dissolved oxygen standard of 6.0 mg/L during non-spawning seasons, and 7.0 mg/L during spawning (Figure 19 & Figure 20). Sites with the greatest amounts of visible algae generally had higher concentrations of dissolved oxygen, however this may be influenced by the time of day sites were sampled.

When algae are abundant, large diel changes in dissolved oxygen occur as photosynthesis increases dissolved oxygen during the day, and respiration reduces dissolved oxygen at night. Dissolved oxygen is also influenced by water temperature (colder water holds more oxygen), re-aeration, and oxygen consumption from fish, invertebrates and non-photosynthetic microbes.

CPW worked upstream-to-downstream while collecting samples. Sites sampled early in the morning and late in the evening will have lower levels of oxygen since photosynthesis is limited by lower light levels. However, cooler water temperatures at sites higher in the watershed, and in the morning and evening, allow the water to hold more oxygen.

Water-quality sondes that can be deployed at a site and periodically measure dissolved would be better for tracking diel pH changes caused by excessive growths of algae that may be stressful for fish. CPW does not own this type of logging equipment.

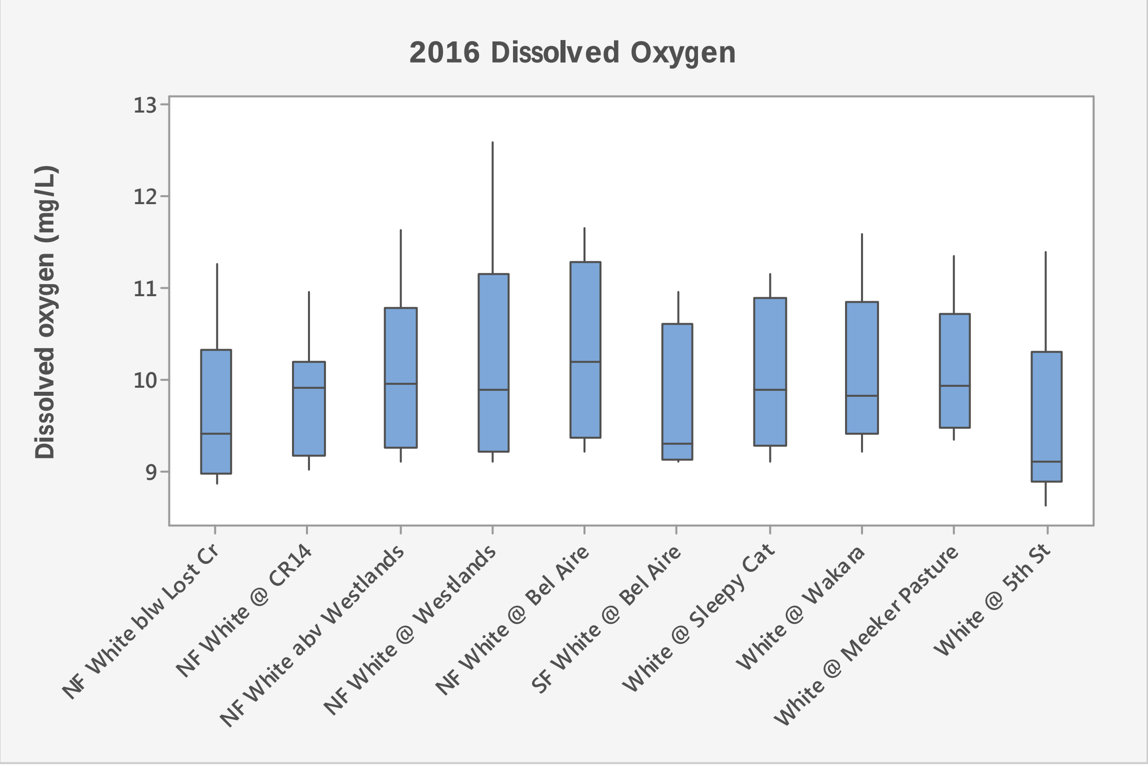


Figure 19. Comparison of dissolved oxygen across all sample sites on the White River.

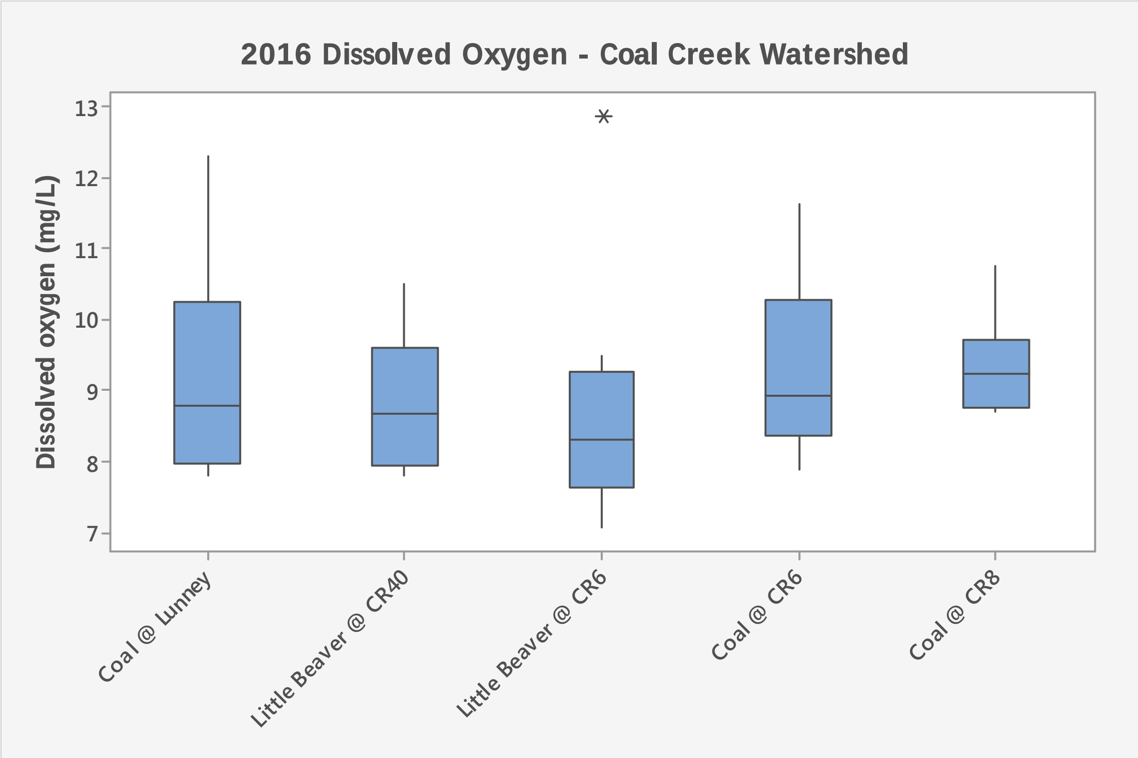


Figure 20. Comparison of dissolved oxygen across all sample sites in the Coal Creek watershed.

VII. Summary and Recommendations

- The filamentous alga impacting angling in the White River is *Cladophora glomerata*.
- Fast-moving current during high flows may temporarily reduce algae by scouring growths from rocks. However, relying on flows to control algae is not practical for the following reasons:
  - re-growth will begin when flows subside
  - scouring flows occur naturally during spring runoff, not during the peak algal growth in the summer (June-August).
  - there is no practical way to increase flows during peak algal growth in the summer
  - relying on flows does not address the underlying cause of the excessive algal growth, which is nutrients.
- Algal growth is limited by nitrogen. This means:
  - Reduction of phosphorus alone is unlikely to reduce algal growth, unless the reductions are significant. Additionally, because *Cladophora* can store excess phosphorus, concentrations must be kept low at all times to effectively control growth. Phosphorus concentrations in the White River watershed are highest during high flows.
  - any additional nitrogen inputs will likely stimulate additional algal growth
  - reducing nitrogen inputs, particularly in the summer, will likely reduce algal growth
- Nutrient availability is sufficient to support nuisance blooms of algae in the North Fork of the White River from County Road 14 (a.k.a Herrell Rd) to the confluence with the South Fork White River, and in the mainstem of the White River down to Meeker. Measuring nutrient availability by monitoring nutrients in the water column is not sufficient because the algae absorb nutrients from the surrounding water. For this reason, CPW recommends more effort be placed on monitoring algae biomass.

- There is no single source of nutrients in the White River watershed, and no single solution. Reduction of both nitrogen and phosphorus is recommended to reduce nuisance algal growth in the White River, with particular emphasis on nitrogen (Dodds & Smith 2016).Human sources of nutrients include:
    - septic systems
    - fish food
    - sediment
    - animal waste
    - fertilizers

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